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THE CONSTRUCTION OF THE WOOD-HOOP SILO

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The purpose of this circular is to explain briefly, yet somewhat in detail, the construction of the wood-hoop silo. Although prepared specifically to supply the demand for this information, prospective silo builders will no doubt desire a statement concerning the merits and limitations of this type of silo. For information concerning the size of silo to build, its location, and silage feeding, the reader is referred to this station's Circular No. 138, "The Silo in California Agriculture," and to Bulletin No. 282, "Trials with California Silage Crops for Dairy Cows."

THE WOOD-HOOP SILO

The essential requirements of any silo are three in number, viz.:

1. An impervious wall to exclude the air and retain the moisture of the silage.
2. A smooth perpendicular wall, which will permit the silage to settle properly.
3. Sufficient strength and rigidity to withstand the bursting pressure of the silage from within, and the force of the wind from without.

The wood-hoop silo will furnish all of these essentials with a minimum expenditure for materials. It has not the durability of masonry or heavier silos, nor the convenience of many commercial silos, except that in smaller sizes it can be readily moved from one foundation to another, a feature of some advantage to tenant farmers. It is not the best silo from the constructional standpoint, but it may be the best from the economic, as it is the cheapest, and furthermore can be farm-made from standard building materials sold at local lumber yards.

The wood-hoop silo is one of the oldest types of silos in use, having been used in different parts of the country for more than twenty years. It is not to be considered an experimental structure in any sense. Although it may be considered a temporary silo, its durability will depend upon the selection of material and the workmanship used. Such silos have been known to be in use after fifteen years.



Fig. 1.—The wood-hoop silo at the University Farm, Davis; 12 feet in diameter by 36 feet high, with 2-foot pit. Cost of materials (in 1917), \$140.

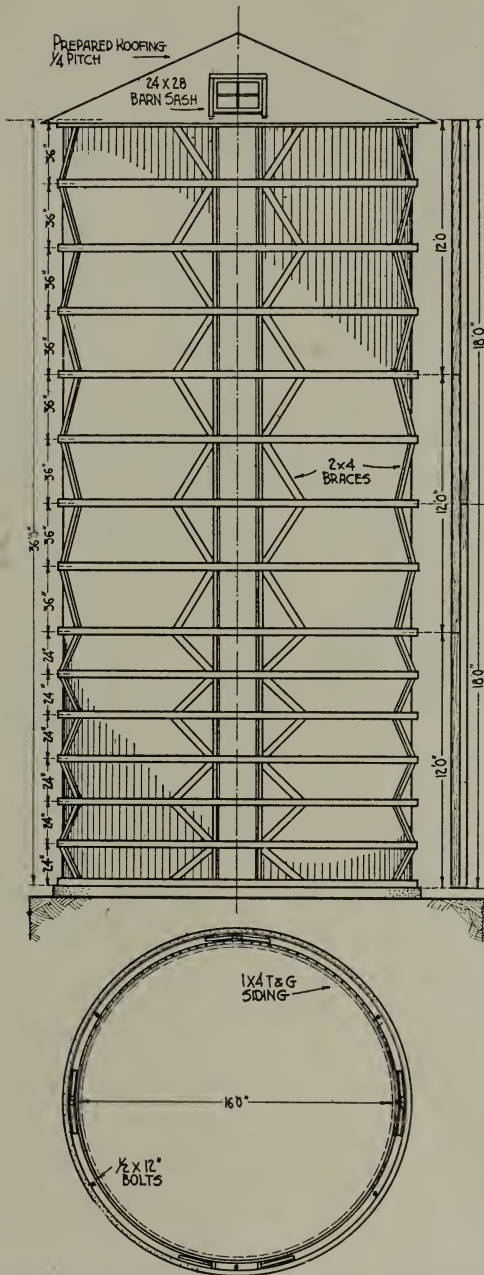


Fig. 2.—Plan and elevation of wood-hoop silo. (See page 16 for spacing of hoops for various sizes of silos.)

CONSTRUCTION

The construction of the wood-hoop silo is simple, for there are but three essential parts to the silo proper: (a) the hoops which resist the bursting pressure of the silage; (b) the diagonal braces between the hoops which are needed to give the silo rigidity; and (c) the lining of tongue and groove staves.

Shrinkage of the Staves.—No provision is made to take up the shrinkage of the staves which must necessarily happen in dry weather when the silo is empty. It has been fully demonstrated, however, that if the fiber has not been crushed, wood will always occupy the same

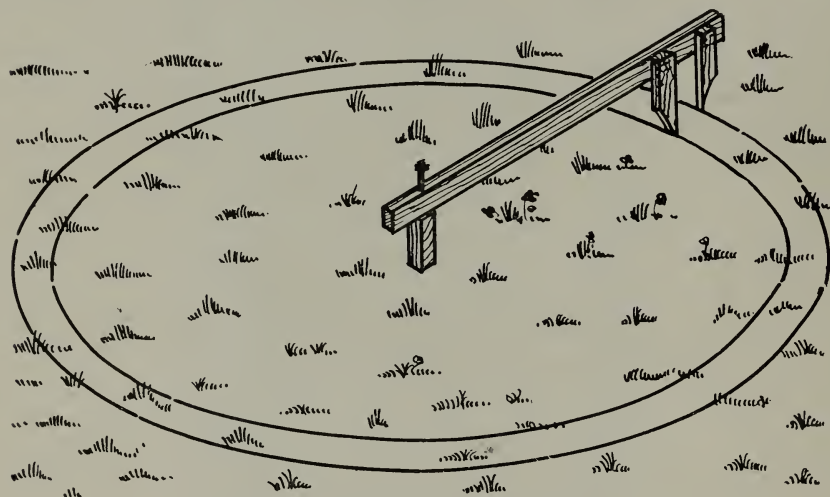


Fig. 3.—Laying out the foundation.

volume with a certain moisture content. As each stave is nailed to the hoops the shrinkage is evenly distributed and does not materially affect the rigidity of the silo. Dry lumber should be used, however, in laying up the wall to insure a perfectly tight wall when moist.

FOUNDATION

Under usual conditions concrete makes the best foundation for the wood-hoop silo. When frost does not interfere the foundation may be simply a ring of concrete, twelve inches wide, deep enough to get a good bearing, or about twelve inches, and high enough to place the silo six inches or more above the ground.

Forms.—In making the foundation wall, lay off two circles from a common center, as shown in Fig. 3. The radius of the smaller circle

should be four inches less than the radius of the silo and the radius of the larger circle eight inches more. Stakes may now be driven on the line inside the inner circle and outside the outer circle. The stakes are then lined with thin lumber or hoop material, as shown in Fig. 4, using care to make level the top of the form, so prepared. A trench is then dug between the stakes so lined, twelve to fifteen inches deep, depending upon the condition of the soil, and the form is ready for filling with concrete.

Concrete.—The concrete should be made of a mixture of about one part cement, three parts sand, and four parts gravel or broken stone. If mixed sand and gravel of good quality is available a mixture of one part cement to six parts mixed gravel may be used. The concrete

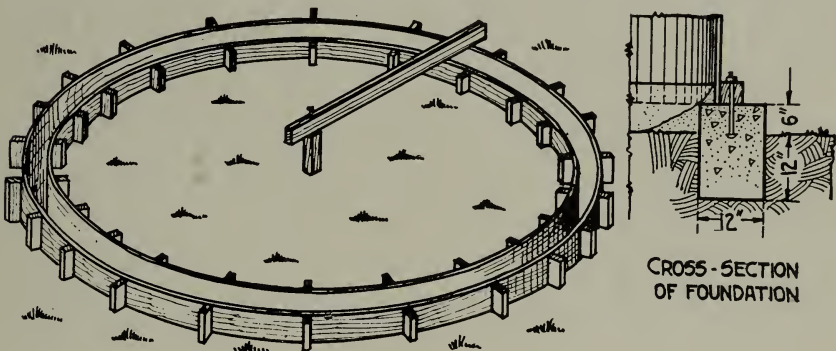


Fig. 4.—Form ready for concrete.

should be placed so wet that it can be poured from a bucket easily and should be given at least a day to set before erecting the silo. Concrete poured in this condition needs very little tamping. Smooth off the top of the concrete level with the form and trowel the surface smooth.

Bolts.—Six $\frac{5}{8} \times 12$ inch bolts, for small silos, twelve feet or less in diameter, and eight bolts for large silos, should be set in the soft concrete, equidistant from one another, and standing about one inch above the width of the hoop material above the concrete. These bolts must be placed accurately on the circle so that they will come through the middle of the hoop when placed on the concrete (see Fig. 4, cross-section of foundation). These can be easily set correctly by cutting a notch in the side of the sweep shown in Fig. 4 and setting each bolt by the notch. Have the notch half the diameter of the silo, plus $\frac{7}{8}$ -inch allowance for the thickness of the wall, plus one-half the thickness of the proposed hoop, away from the pin at the center. If a

12-foot silo is to be made with hoops six bands thick, of $\frac{3}{8}$ -inch material, then the notch would be $6' + \frac{7}{8}" + \frac{11}{8}" = 6' 2"$ from the center pin. The most satisfactory bolts are made of pieces of $\frac{5}{8}$ -inch iron, 14 inches long, threaded on one end and bent at right angles two inches from the other end. These bolts will not turn in the concrete.

HOOPS

Material.—The material for the hoops may be any thin lumber free from knots, dressed to size, $\frac{3}{8}$ -inch thick and $2\frac{3}{4}$ to 4 inches wide. Sugar pine, redwood, white cedar, and Douglas fir have all been used successfully. Batten stock which can be procured in all yards is quite satisfactory for the smaller silos. For silos larger than ten feet in diameter material $\frac{3}{8} \times 3\frac{3}{4}$ inches is more satisfactory.

MAKING THE HOOPS

The first step in making the hoops is to prepare a fairly smooth floor of 2-inch material, about two feet larger in diameter than that of the proposed silo. This floor is usually a temporary floor made of 2-inch planks laid across three or four pieces of 2×4 -inch material, as shown in Fig. 5, and nailed down. The next step is to build the master hoop or form in which the hoops are made. First describe a circle on the floor with a radius equal to one-half the inside diameter of the silo plus $\frac{7}{8}$ inch allowance for the thickness of the staves plus the thickness of the hoop, plus the thickness of three bands of the hoop material making up the master hoop. This line will come at the outside of the master hoop. If a silo twelve feet in diameter with hoops six-ply thick is to be made, then the two nails in the stick to be used as a compass will be $6' + \frac{7}{8}" + (\frac{3}{8}" \times 6) + (\frac{3}{8}" \times 3) = \text{total } 6' 4\frac{1}{4}"$ apart. One nail is driven in the center of the floor and the other scratches the line as the stick is swung around.

A number of blocks about 10 inches long are now cut from 2×3 inch or 2×4 inch material, according as the hoop material is 3 or 4 inches wide, with one square end and one sloping end. See blocks around outside of master hoop in Fig. 5. These blocks are securely nailed to the floor outside of the line with the square end exactly on the line. They cannot be fastened too securely as there is considerable strain on them when the hoops are removed from the master hoop. The blocks should be spaced every fifteen inches. Next these blocks are lined with the first layer of the hoop material, breaking joints in the center of the blocks. This is nailed in place with 4d-nails. The

next two layers are put in the same way except that the end of the piece is started about half-way between two blocks, instead of at a block in the first layer. This makes a tighter fit as the hoop material has a tendency to straighten out near the ends if started with the end at a block. The third layer should be put in with 6d-nails. After putting in the three layers if there are any places where the layers are not tight together, the carpenter should go around and drive small nails through all three clinching them on the outside by driving against a heavy sledge hammer or something similar. It is also a good plan to drive one or two 8d-nails, between each two blocks, inclined through the lower part of the hoop into the floor. In this way the



Fig. 5.—Making the hoops.

outside of the hoop can be drawn accurately to the line at all points. Do not leave any nail heads protruding on the inside of the master hoop as the other hoops must be slipped out of the master hoop when finished. It helps greatly in removing the hoops to rub the inside of the master hoop with candle grease or paraffin to make it smooth. Successful hoop-making depends on a good master hoop.

Next a number of swinging blocks or sweeps are cut from the same material as the short blocks, about three feet long. Notice them inside of the hoop in Fig. 5. A hole is bored with a small bit, to fit a 30d-nail through the sloping end where it is about 2 inches thick. In placing these sweeps butt the square end tightly against the inside of the master hoop, with the sloping end pointing to the center of the circle. Then drive a 30d-nail through the hole which was bored. This leaves the sweep free to swing into various positions. Put one of these about every 30 inches around the master hoop. Before beginning to make

the hoops, it will facilitate the work if a tool be made for springing the hoop material into place. Get half of a leaf of a broken 2 or 2½-inches wide auto-spring and have it flattened out at the thick end into a chisel-like tool, the blade tapering off gradually to a thin edge. The end should be about as wide as the hoop material. Also procure a good sound block of hard wood, about 2 × 4 × 12 inches, cut square on the ends.

Now begin to build up the hoop by first swinging all the sweeps in the master hoop to the right, away from the master hoop. Place a piece of the hoop material inside of the master hoop with the smooth side against the master hoop. Now standing inside of the master hoop begin at the left-hand end of the piece already laid in and swing the sweeps up one by one against it until the strip is held tightly against the master hoop. The next piece should always be added on to the right hand end of the piece just put in and the sweeps tightened as before. The end of this second piece (if two pieces reach around as in small silos) will lap over the end of the first piece laid down. Before cutting it off take the hardwood block you have provided and placing it against the end of the last strip laid down with your foot on the block to hold it firm, drive it endwise to take all the slack out of the strip.

When the strip will not move any more, mark the overlapping strip to cut it off about ¾-inch longer than it apparently will go in. Loosen a couple of the sweeps and saw the strip off at the place marked. Now take the chisel-like tool and placing it behind the end just sawed off hook it on to the end of the other strip. Sit down on the floor and use your foot against the chisel handle as a lever while another man uses the hard wood block and drives the strip into place. You cannot get them to fit too tightly. A little practice will show you how much to allow when sawing off and how to use the chisel to advantage. Now loosen all the sweeps and put in the next layer in the same way, always keeping the joints several feet from those on the last layer. After three layers have been put in you may begin nailing with 3d-nails, only using a few nails near the ends of the pieces where they do not lie down smoothly. Be sure you never use any nail which will reach through the hoop you are making into the master hoop. All following layers may be nailed in as you go with enough small nails to keep them up tight. When the last layer is put in it is nailed in with large nails which will reach almost to the master hoop. A measurement on top will show what nails to use. These nails should be about five inches apart all around alternately near the top and bottom of the hoop.

After finishing the nailing inside, the hoop is now ready to be lifted from the master hoop. A mattock (grubbing hoe) is the best tool usually available for this work. Raise the hoop a little with a bar and slip the blade of the mattock under, then follow around shoving sideways on the handle. This will raise the hoop little by little. When this first hoop is about half way up all around, the two or three outside joints should be nailed down so that the outside layer will not spring off when the hoop is removed from the form. Before removing it farther, take a steep tape and carefully measure the distance around the outside of the hoop above the master hoop. This distance is divided into four equal parts. Now begin by making a heavy pencil mark across the top of the master hoop at any starting point, and also make a mark across the top of the hoop at the same



Fig. 6.—Detail of hoops.

point. Make a figure (1) on the outside of the master hoop and on the inside of the hoop beside these marks. Then measuring around the hoop from this point make the same marks one-fourth of the way around, calling these marks (2). Always measure toward the right from No. 1 when standing inside the hoop. Do the same for the third quarter. When the fourth quarter point is reached the marks should not be on the quarter point but should be one-half the width of the door to the right of this point. With the usual 20-inch opening this mark should be 10 inches to the right of the quarter point (when you are inside the hoop).

Now take the hoop entirely out and nail it on the outside, just as it was nailed on the inside, and put the galvanized iron plates over the joints. These plates being about $\frac{1}{4}$ inch wider than the hoop, should protrude a little at both edges so that it may be crimped over with a hammer after the plate is nailed on. Use the large nails to put them on with about ten in each plate. The remaining hoops are all made in the same way. Be sure not to forget to mark the quarter points on the top of each hoop, from the marks on the master hoop,

before it is removed from the form. The hoop to be set on the foundation should have about three strips tacked across it before removing from the master hoop, to keep the hoop round until set.

ERECTING THE HOOPS

The first move is to bolt a hoop selected, to the concrete, taking care to get the marks in position so that the door will come where desired. Place mark No. 4 (the one which was not at the quarter point) at the right hand side (when standing inside the silo) of the proposed door position. Having placed the hoop in the right position, begin by boring a hole through the center of the hoop directly over one of the bolts. Now enter this bolt a little way into the hole to hold it in position and move to the next bolt. After getting three or four entered, go all around and be sure that the bolts stand about in the middle of the hoop. Then proceed and bore the remaining holes and fasten the hoop down securely. Before putting it entirely down, it is a good plan to pour some rich cement mortar under it and bed the hoop in it to make a tight fit.

Marking Off and Placing the Guides.—Take three good straight pieces of 2×3 -inch or 2×4 -inch material about 18 feet long and one piece about 12 feet long. These will be used as temporary studs to keep the hoops in line before the staves are put on. Place these four pieces side by side with ends even and with the square strike a mark across them to show the level of the bottom of each hoop when it is placed in position. The first mark should not be 2 feet from the bottom, but one-half width of the hoop less than two feet, so that when the bottom of the hoop is at the mark the center will be at the 2-foot mark. From this point the marks will be two feet apart up to the point where the hoops are placed further apart. Be sure to have the hoops always where the stave joints are to break, so placed that the staves will reach to the middle of the hoop. In a 30-foot silo the staves would break at the 12-foot and 18-foot levels, so the middle of the hoops should be accurately at 12 feet and 18 feet, respectively. If these are placed accurately, all the stave material can be cut before erection begins.

The three long temporary studs are now stood up outside of the bottom hoop at three of the four quarter-marks on this hoop. Have the studs stand on the concrete and have the same edge of each stud at the mark on top of the hoop. Now take a 20d-spike and drive it through the stud into the hoop, drawing the stud up tightly against the hoop. These studs are plumbed by using two braces at right angles fastened to stakes driven in the ground as shown in Fig. 8.

Before erecting the last stud, place four more of the hoops on top of the first one, taking care to have the respective numbers on the hoops above each other. This will save moving them around afterwards. After placing this last stud, push the top hoop up as high as you can reach easily and drive a spike in each stud under it to hold it temporarily in place. Then raise the next one and drive the spikes under it on the marks which are just below six feet. Place the other two hoops similarly above the 4 and 2-foot marks, respectively.

The hoop is fastened in place at the 2-foot level with the marks on this second hoop exactly above the similar marks on the first hoop at the edge of the studs. This is fastened by driving a 20d-spike

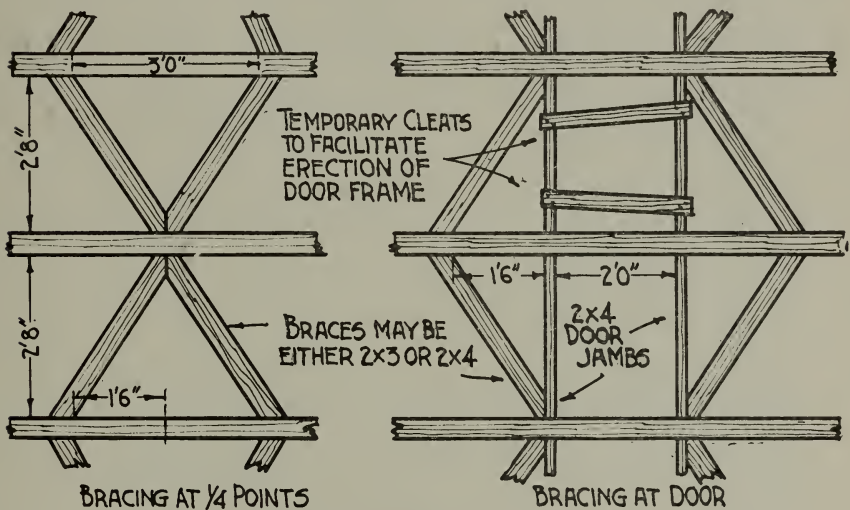


Fig. 7.—Detail of braces.

through the stud into the hoop. The mark on the stud should now be at the bottom of the hoop and the mark on the hoop at one edge of the stud. The next two hoops may be similarly fastened in place while standing on the ground. Before going farther some more temporary studs of 1×4 -inch or 1×6 -inch material are stood up outside the hoops half-way between each pair of the original four studs. These should be nailed securely to the hoops with 8d-nails. Be sure that the hoops are kept at the same height at these last studs as they are at the first four studs. They are often quite easily shoved up or down so they should be measured each time before making them fast. This will keep each hoop level all around.

The Braces.—The braces, usually of 2×3 -inch material, are set at the quarter-points to give the silo rigidity. Figs. 7 and 8 show the

shape and location of the braces. These braces should not be set flush with the inside of the hoops as they will lie slightly inside of the hoop line at their mid-point and interfere with the laying of the staves. It is a good rule to set them back the thickness of one band $\frac{3}{8}$ inch from the inside of the hoop. The braces should be nailed together in pairs before being put into the frame as they are then much easier placed. The cuts along the line where the braces are nailed together should be at such an angle that when nailed together in pairs the braces will not lie in one plane but will conform to the curve of the hoops. A little practice will show how to cut these to make them fit well. The point of the braces where they are nailed together should not be nailed to the hoop until after the staves are laid up to that point. The short studs set at the two sides of the doorway, 20 inches apart, are set flush with the inside of the hoops and securely nailed in place.

It is now in order to build some scaffolding for putting up the next three hoops. Take four of the 2×10 -inch or 2×12 -inch planks which made up the temporary floor and lay them across the hoop at the 6-foot level, as shown in Fig. 8. Always try to have them resting near to one of the studs so as not to bend the hoops out of place. Now fasten the 8-foot hoop in place as the others were and take up another from the ground. This should be taken over the top of the low stud and fastened in place before another is pulled up. Move the scaffold up when you can not work easily from it. Usually it is moved up every six feet.

When the last mark on the short stud is reached, another piece of studding is added on, as shown in Fig. 8, and the marks put at the correct places on it. Be sure in adding on this extension to the stud that the new piece is on the same side of the original piece as the marks on the hoops are on, so that a straight line will be formed from the bottom of the silo to the top by which to line up the hoops correctly.

This stud is now the long one and the following hoops must be taken up over the other side until in turn new ones are added on to them. By alternating back and forth no difficulty will be experienced in taking up the hoops. After the first seven or eight are up it will be necessary to pull them up with ropes, which is not difficult because of their lightness. Continue the 1×4 -inch studding to the top also.

THE STAVES

Material.—The staves are of 1×4 -inch tongue and groove lumber, either ordinary pine flooring or clear redwood. Specially milled staves



Fig. 8.—Erecting the hoops.

should be milled full on the outside so as to fit well when laid in the circular hoop.

Placing the Scaffold.—Before beginning to lay the staves the scaffolding to work on must be placed, one 2×10 -inch or 2×12 -inch plank will be required for each 6 feet of height of the silo. At the 6-foot level, place a plank with one end in the doorway and the other end resting on the hoop near the next quarter-point to the right of the door. Place planks every 6 feet to the top directly above each other.

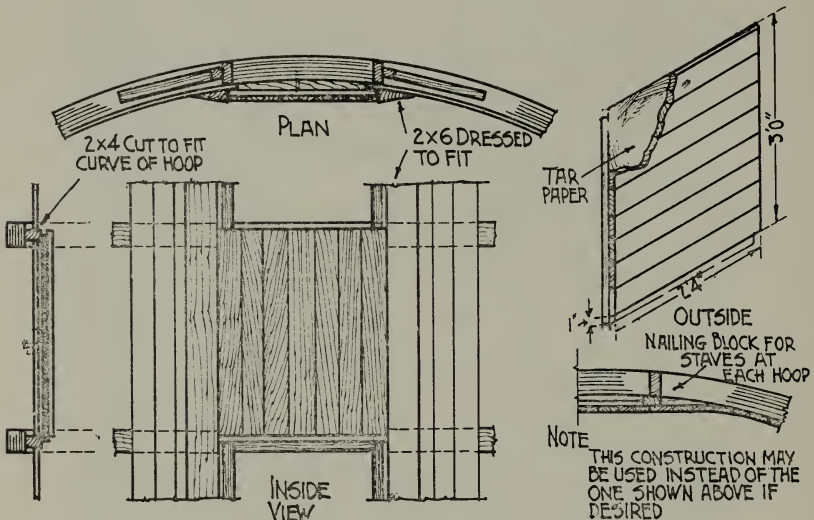


Fig. 9.—Detail of door frame and door.

Start the first stave at the right side of the door and have it flush with the inside edge of the door studs. This will leave a 20-inch opening in the clear. Run this stave from bottom to top and then lay the next stave breaking joints with the first one. Two nails should be put in each stave at each hoop, one blind nail and one top nail, except at the ends and joints of the staves where only a top nail is needed. Have the man on the top scaffold keep sighting down the staves as they are laid to keep them in true perpendicular line. It is very easy to get the line out of true and difficult to get it back again. A plumb line may be used to advantage.

While laying the staves it is a good plan to tear off the temporary studding as you come to it, and if the staves do not line just right, because the hoops are out of line, the studding should be ripped off several feet in advance of the staves so that the hoops can adjust themselves.

After passing the first set of braces with the stave laying, shove the point of the pair of braces in against the staves and nail them fast to the hoop. Do this at each set of braces as they are passed. As it becomes necessary, keep moving the plank around, always leaving the one end in the doorway.

When the staves are laid about three-fourths of the way around, the scaffold planks can no longer be used as the doorway will not allow them to swing farther. They will then be taken down and the workman must stand astride of the hoops to finish the stave laying. This is not at all difficult and the work will proceed almost as rapidly as when the planks are used. Cut the last stave off flush with the door stud as the first one was started.

THE DOORWAY

The doorway is continuous from top to bottom adding to the convenience of the silo. It is shown in detail in Fig. 10. The door jambs are nailed on as shown about 1 inch back from the edge of the doorway.

THE DOORS

The doors are made of two thicknesses of flooring with tarred paper between. After the doors are made up they are sawed down the sides on the correct bevel to fit the door jambs. Each door fits directly on top of the preceding one, the two layers breaking joints about an inch, as shown in Fig. 9. When putting in the doors as the silo is filled, it is well to seal them against air-leakage by the use of soft clay mud. Smear the top of the last door and the sides of the one being put in with it. Then after it is in, fill the crack all around the door with the clay and it will be airtight as long as the damp silage is against it.

THE CHUTE

A chute is quite necessary and should extend from about six feet from the ground to the top. For economy it can well be built of plain barn boards. (See Fig. 10.)

THE ROOF

A roof on a silo is not necessary, although it will protect and strengthen the silo, assist in preventing the silage from drying out, keep out rain and birds, and improve the appearance of the silo. It may be framed either to form a cone, or an octagonal pyramid, as

shown in Fig. 11, and covered with shingles or prepared roofing. It is often convenient to build the roof after the silo is filled.

SPACING OF HOOPS AND LENGTH OF STAVES

30-foot silos:

Total of thirteen hoops, 6-ply thick.

First seven hoops spaced 24 inches between centers for 12 feet.

Next six spaced 36 inches between centers for 18 feet.

Staves made of 18 and 12-foot pieces and 12 and 18-foot pieces alternately.

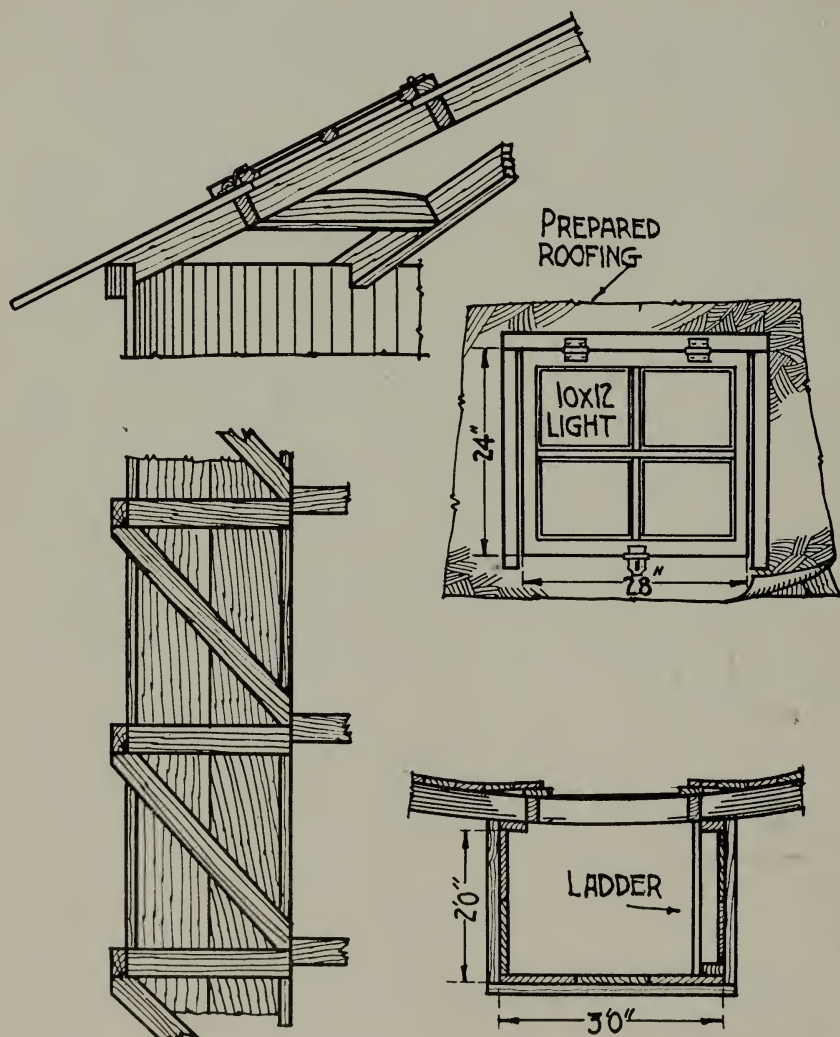


Fig. 10.—Detail of roof window and chute.

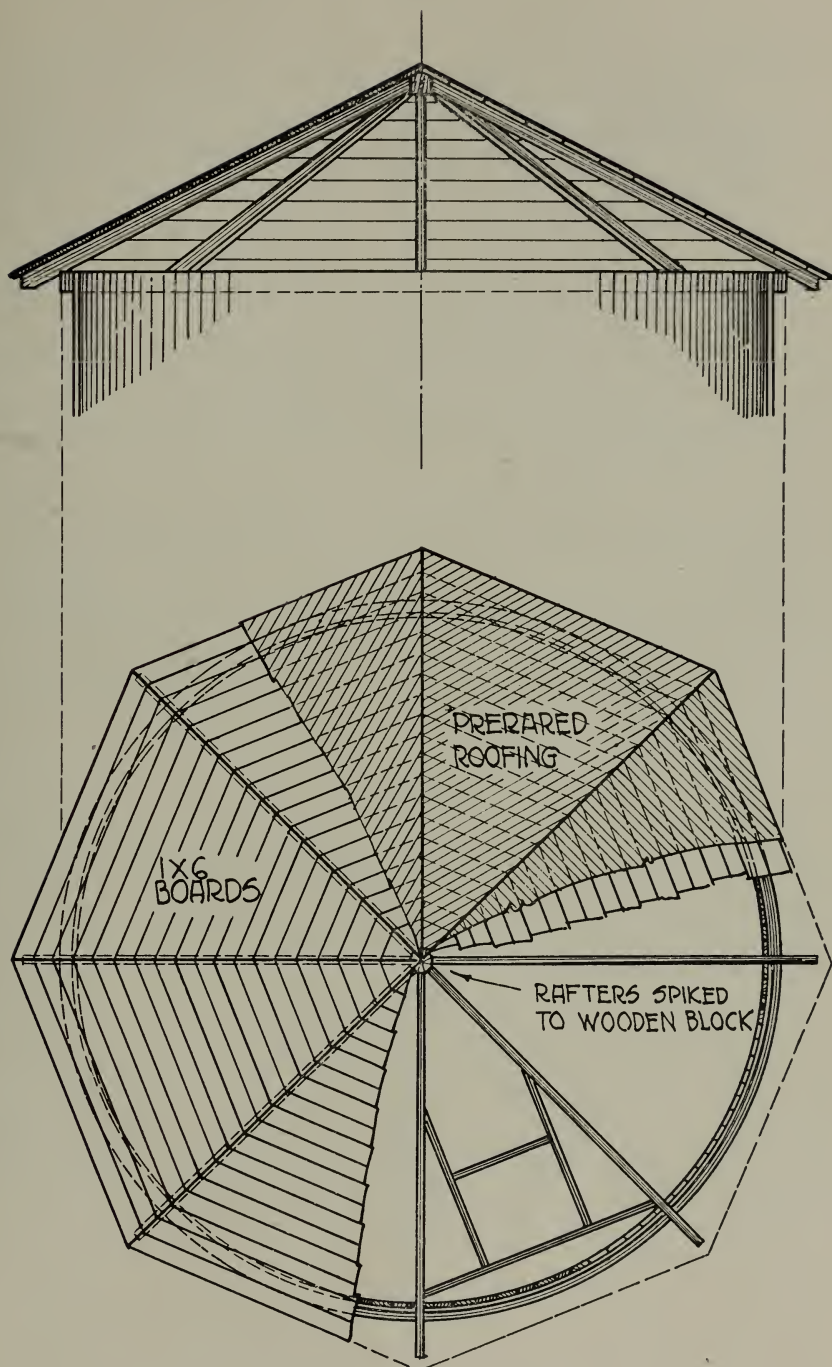


Fig. 11.—Detail of roof.

36-foot silo:

Total of fifteen hoops, 6-ply thick for 10 and 12-foot silo; 7-ply thick for 14 and 16-foot silos.

First seven hoops spaced 24 inches between centers for 12 feet.

Next eight hoops spaced 36 inches between centers for 24 feet.

Staves made of two 18-foot pieces and three 12-foot pieces alternately.

42-foot silo:

Total of nineteen hoops, 6-ply thick for 10 and 12-foot silo; 7-ply thick for 14 and 16-foot silo.

First ten hoops placed 24 inches between centers for 18 feet.

Next five hoops placed $28\frac{3}{4}$ inches between centers for 12 feet.

Next four placed 3 feet apart for last 12 feet.

Staves made of 18, 18 and 6-foot pieces, and 16, 14 and 12-foot pieces alternately.

TREATING THE INSIDE OF SILO AND THE HOOPS

A coat of tar will improve the tightness of the silo. The less durable wood can be treated with creosote oil to preserve the wood. The silo can be relined on top of first lining when needed.

The top of the hoops where exposed to the weather can well be coated with heavy tar to protect them from moisture.

GUY WIRES

The silo is a light structure with a large amount of surface exposed to the wind. To protect it when empty, it must either be attached to adjoining buildings or thoroughly guyed to posts set properly. Failure to do this will often result in the destruction of the silo.

BILL OF MATERIALS

The following bill of materials does not include plank for a temporary floor on which to make the hoops or several pieces needed for scaffolding. The temporary floor should be about two feet larger than the diameter of the hoops. One 2×10 or 2×12 -plank for scaffolding will be needed for each six feet of height.

MATERIAL FOR WOOD-HOOP SILOS—(Continued)

		DIAMETERS							
Height		10 feet		12 feet		14 feet		16 feet	
Prepared roofing		2 squares		2 squares		3 squares		3 squares	
Door jambs made of 2" X 6" cut as shown in Fig. 10.	30'	60 linear ft.		All diameters same.					
	36'	72	" "	" "	" "	" "	" "	" "	" "
		84	" "	" "	" "	" "	" "	" "	" "
Nails: The 8d-nails should be galvanized. The remainder com- mon wire.	30'	Lbs.	d.	Lbs.	d.	Lbs.	d.	Lbs.	d.
		7	20	7	20	7	20	7	20
		53	8	61	8	69	8	77	8
		8	6	10	6	12	6	14	6
		5	4	6	4	7	4	8	4
	36'	8	20	8	20	8	20	8	20
		73	8	81	8	89	8	97	8
		10	6	12	6	14	6	16	6
		7	4	8	4	9	4	10	4
	42'	9	20	9	20	9	20	9	20
		83	8	91	8	99	8	107	8
		11	6	13	6	15	6	17	6
		8	4	9	4	10	4	11	4

One piece of No. 26 galvanized iron, 12 inches long and a little wider than the hoop material, for every outside joint on the hoops. If two pieces reach around a hoop, then two pieces of iron will be needed for each hoop, etc. (See Fig. 6.)

Three or four guy wires with two eye-bolts for each should be provided, viz.:

36 feet long for 30-foot silo;

42 feet long for 36-foot silo;

48 feet long for 42-foot silo.

Five or six strands of No. 9 wire make a good guy wire.

Posts will be needed to which to attach guy wires.